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Ultrasonic testing for geomembranes

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Ultrasonic testing consists of nondestructive evaluation of materials and structures. It uses mechanical waves with frequencies higher than the audible sound range (> 20 kHz). Mechanical wave propagation in solid materials is correlated to various properties and material conditions. It allows one to determine material properties, detect damage or discontinuities in materials and systems, and assess condition of materials and structures. Ultrasonic testing can be used for quality control (QC) during manufacturing and construction phases and for monitoring performance of a material or structure during its service life.

Overall, it provides simple, fast, and accurate assessment. Common types of mechanical waves used in ultrasonic testing are compression waves (primary or P-waves), shear waves (secondary or S-waves), and Rayleigh waves.

With geomembranes

Ultrasonic waves are introduced to a geomembrane from a surface of the material; the transmission characteristics determine properties and conditions. Two primary methods are used:

- *Pulse-echo test method*. Waves are transmitted and received from the same surface of a material. This method is quite common. Waves can be transmitted and received using a single transducer or using two transducers (one for transmitting, one for receiving).

- *Through-transmission test method*. Waves are transmitted from one surface of a material and received from the opposite surface. Access to only one surface of a geomembrane is required in pulse-echo testing, whereas access to both sides of a geomembrane is required in through-transmission testing. Since the travel distance of waves is shorter in through-transmission testing, transmitted wave energy is higher than in pulse-echo testing.

In general, compression waves have been used for testing geomembranes. P-wave transducers with center frequencies in the range of 1 MHz and 20 MHz are appropriate . The use of other wave types has been limited.

The analysis of wave transmission characteristics can be conducted in time-domain (using time vs. amplitude records of waves) or frequency-domain (frequency vs. amplitude records of waves). Wave travel time, associated velocity, and attenuation (determined based on wave amplitude measurements) are commonly used. In addition, waveform transmission through a test material is investigated, and waveform transmission between materials is moni-

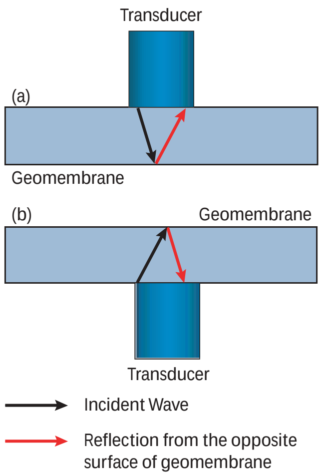

***Figure 1**. Pulse-Echo Test arrangements using a single transducer: The transducer can be placed above (a) or below (b) a geomembrane. No pressure is applied to the geomembrane in (b). Arrangement (b) can be used to obtain a thickness measurement without considering pressure effects.*

** Waves are shown at exaggerated angles for clarity of graphical presentation.*

tored (e.g., multi-layered systems). Furthermore, frequency distribution of a waveform can be determined.

Nondestructive testing

Wave propagation velocity is used to determine thickness, density and elastic properties. Attenuation of waves in solid materials is used to determine microstructural properties. Travel time, amplitude and frequency distribution measurements are used to assess the condition of materials; that is, to identify damage and defects and determine the quality of the bonds in multi-layered systems.

Ultrasonic testing is a well-established branch of nondestructive testing. Various types of equipment are commercially available from several manufacturers. Portable, lightweight equipment is available for field applications as well as larger setups with sophisticated data acquisition and analysis arrangements that are suited for laboratory use. Testing equipment can be set up such that measurements can be readily made by factory or field personnel (without significant training in ultrasonics). In geomembranes, wave transmission occurs in microseconds; therefore, measurements can be conducted quite quickly. Setups with a single transducer can be used in tests. Setups with multiple transducers can cover large areas in short periods of time. Also, transducers may be installed in manufacturing lines for automated data collection during production. Furthermore, transducers may be installed on geomembranes and monitored over time.

Geomembranes can be tested both in the laboratory and field using ultrasonic testing. Tests can be conducted on the parent material and seams. Tests can be conducted during manufacture of geomembranes for quality control, during construction for seam inspection and overall quality control of installed geomembranes, and also for monitoring the long-term performance of geomembranes in service as well as in forensic analysis of failed systems. As such, significant time and cost savings can be achieved by using ultrasonic test procedures in the evaluation of geomembranes. Specific applications of ultrasonic testing include:

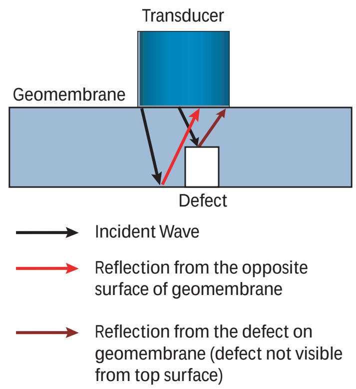

***Figure 2**. Transmission in a geomembrane with a defect on the underside.*

** Waves are shown at exaggerated angles for clarity of graphical presentation.*

• Determination of physical properties of geomembranes such as thickness and density.

• Determination of elastics constants for geomembranes such as modulus of elasticity.

• Determination of condition of geomembranes, including defects such as surface defects (e.g., scratches and cuts on the visible top surface of a geomembrane, defects on the underside of a geomembrane not visible from the surface), inner defects (e.g., discontinuities within geomembranes that are not visible from surface), and defects that penetrate the entire thickness of a geomembrane (e.g., pinholes).

• Determination of the quality of a bond between geomembrane sheets in seam applications.

• Determination of the quality of a bond between geomembranes and various penetrations and structures (e.g., pipe boots, attachments to various concrete structures).

• Determination of type of material (e.g., air, water or soil) in contact with a geomembrane for detection of leaks.

• Determination of various other properties of geomembranes established using empirical correlations for a specific type of geomembrane.

Resources

Detailed information about ultrasonic testing is provided in *Nondestructive Testing Handbook, Volume Seven, Ultrasonic Testing* (1991, ed. P. McIntire) published by the American Society for Nondestructive Testing, www.asnt.org. The newly adopted ASTM D 7006-03 (*Standard Practice for Ultrasonic Testing of Geomembranes*) provides a summary of equipment and procedures for pulse-echo testing of geomembranes. Seam inspection guidelines are provided in ASTM D 4545-99 (*Standard Practice for Determining the Integrity of Factory Seams Used in Joining Manufactured Flexible Sheet Geomembranes*) and ASTM D 4437-99 (*Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes*). A field device for ultrasonic evaluation of seams in prefabricated bituminous geomembranes is described by Breul, Carroget and Herment in "Automatic ultrasound seam tester for bituminous geomembranes—development and field results," *Proceedings of Sixth International Conference on Geosynthetics* (1998). Test programs related to seam inspection are described in *Designing with Geosynthetics* by Koerner (1998). Detecting defects and determining thickness of geomembranes are described in Yesiller and Sungur's "Evaluation of geomembranes using an ultrasonic method," *Geotechnical Testing Journal*, vol. 24, no. 3 (2001); and Yesiller and Cekic's "Determination of thickness of smooth geomembranes," *Geotechnical Testing Journal*, vol. 24, no. 4 (2001), www.astm.org. GFR

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